UNITED STATES DEPARTMENT OF AGRICULTURE

# FOREST SERVICE

RMD

## DOUGLAS-FIR BEETLE EVALUATION
## CALIFORNIA REGION
## 1964 - 1967

Annex
SB
763
.C2 U55
1967

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE
DIVISION OF TIMBER MANAGEMENT
630 SANSOME STREET
SAN FRANCISCO, CALIFORNIA 94111

NOVEMBER 1967

6200-7 (6/65)

U.S. GOVERNMENT PRINTING OFFICE : 1965 O—777-887

# DOUGLAS-FIR BEETLE EVALUATION
# CALIFORNIA REGION
# 1964 - 1967

## INTRODUCTION

In 1966, the Douglas-fir beetle (Dendroctonus pseudotsugae Hopk.) killed an estimated 249 thousand old-growth Douglas-fir trees on 1.6 million acres in Del Norte, Humboldt, Siskiyou and Trinity Counties in northwestern California. This represents a total gross volume mortality of approximately 796 million board feet and a net volume mortality of approximately 535 million board feet. The greatest volume of this mortality occurred on National Forest lands (Six Rivers, Klamath and Shasta-Trinity National Forests) and on the Hoopa Valley Indian Reservation.

The 1966 epidemic of Douglas-fir beetles was by far the worst ever recorded in California's history. The only other known outbreak of any magnitude occurred in 1954. That year, 100 million board feet were killed on 200 thousand acres in the Klamath and Trinity River drainages.

Results of beetle population surveys made in the fall of 1965 indicate that the vast amount of damaged and uprooted Douglas-fir trees left in the wake of severe December 1964 storms and floods triggered the outbreak. The results of similar surveys made in 1966 indicate that the natural resistance of green trees to attack, plus poor brood survival in green trees, caused the outbreak to collapse by fall of 1966.

In early summer 1967, a specially designed double-sample survey using 9 by 9-inch format, 1:8,000 color aerial transparencies with ground checks, was used to measure the tree mortality that occurred in 1966.

## HISTORY OF THE EPIDEMIC

### 1964

Except for a few small infestation centers, the Douglas-fir beetle was endemic in California through fall of 1964. In December 1964, heavy snow and rain storms and subsequent severe flooding caused a large unestimated volume of Douglas-fir to be uprooted or damaged throughout north-coastal California.

### 1965

Immediately following the storms and flooding it was recognized that a Douglas-fir beetle buildup could develop in the damaged trees and later spread to healthy trees. Forest land managers were alerted to this possibility and as a preventive measure they were encouraged to salvage and remove as much of the downed material as possible before beetle emergence

in April 1966. While a strong effort was made to salvage the infested material before beetle emergence, the job could not be done as there were too many down trees spread over too large an area of rough terrain. Salvage problems were hampered further by the widespread destruction of existing road systems during the floods.

In order to better judge the potential of a beetle epidemic in 1966, an extensive detection and evaluation survey was made in August through mid-October 1965, on the Six Rivers and Klamath National Forests. On completion of this survey, a general beetle population buildup in the down and damaged Douglas-fir was indicated and the prediction was made that green trees would be attacked in the spring of 1966. How severe the attacks would be and over what area they would occur, were questions that could not be answered.

1966

In early May, on-the-ground examinations detected the first stages of an epidemic that later caused catastrophic losses of Douglas-fir. The adult beetle broods survived very well under the bark of unsalvaged storm-damaged slash through the mild winter of 1965-1966; they emerged for the most part by the end of April; and they made successful attacks in standing green trees.

The Forests were notified of this development. It was recommended that in their continuing salvage program, they include green-infested trees.

In the period April through June, below-normal precipitation and above-normal temperature prevailed. This condition may have decreased to some extent the resistance of healthy trees to beetle attack during the critical period when hoards of beetles were emerging from the slash and attacking standing trees.

In late July and early August, the first reports of fading Douglas-fir were received from the field. However, it wasn't until late September that the magnitude of the problem was realized.

In November 1966, an aerial flight was made to sketch map the boundary of the infestation and to delineate the areas of heaviest mortality. The entire infestation covered 1.6 million acres; heavy concentrations of tree killing occurred on 400 thousand acres.

In order to determine the trend of the beetle population, a survey was made late in the fall similar to the one made in 1965. This time, standing trees were sampled for that was where the beetles were.

A comparison of the results from the two surveys indicated that the peak of the infestation had already been reached in the summer of 1966 and a downward trend was predicted for 1967.

In 1965 when the beetles attacked the storm-damaged host material (slash), nearly all attacks were successful. Brood establishment was good and

survival was very high. The 1966 survey showed quite a different situation. On the average, of the standing trees attacked, 14 percent successfully repelled the beetles; the cambium of these trees was green and their chance for survival was good. Another 38 percent of the trees attacked were killed, but no broods developed. As a result, about one-half of the trees attacked in 1966 absorbed more beetles than would emerge from them in the spring of 1967. This downward trend, probably due to the natural resistance of green trees to attack and poor brood survival in green trees, was reflected in the attack and brood density counts made in the fall surveys of 1965 and 1966.

| | | Attack Density | | Overwintering Brood Density | |
|---|---|---|---|---|---|
| Date | Host Condition | Sq. Ft. Bark Examined | Ave. Attacks Per Sq. Ft. | Sq. Ft. Bark Examined | Ave. No. Beetles Per. Sq. Ft. |
| Fall, 1965 | Slash | 800 | 1.3-successful<br>0.0-aborted | 80 | 19.7 |
| Fall, 1966 | Standing Trees | 199 | 3.3-successful<br>1.2-aborted | 199 | 4.5 |

The fall 1966 surveys also showed that on the average, 55 percent of the attacked trees had faded and 45 percent were still green. From these data it was difficult to make a reasonable estimate of the amount of mortality that occurred in 1966 because fading, the most noticeable visual response of trees attacked and killed in 1966, was not complete until the early summer, 1967.

1967 - Current Situation

Observations from April through September confirmed the predicted downward trend of the beetle population and a near normal situation appeared to exist. In fresh slash and recent fire-killed trees, the emerging overwintering beetles made successful attacks. For the most part, attacks on green trees were found aborted, but a few pockets of persistent infestation were reported in September when 1967 attacked trees began to fade.

While the natural resistance of green trees to attack and poor brood survival must certainly have played a major part in the continued downward trend of the beetles in 1967, the number of successfully attacked green trees was even lower than anticipated. One factor which, when coupled with the natural resistance of green trees to attack, might account for the almost complete collapse of the beetle population in 1967, is the weather conditions at the time the overwintering broods were emerging and attacking in the spring of 1967.

The prevailing weather during the period of April through June 1967 was one of normal precipitation with temperatures averaging 9° below normal. As a result, beetle emergence occurred four to six weeks later

in 1967 than in 1966, and instead of emerging and attacking "en masse" within a period of a few days as in 1966, daily emergence was believed to be scattered and prolonged over a period of several weeks. At the same time, with moisture more readily available than in 1966, tree vigor remained high, enabling the trees to successfully repel the prolonged light attacks.

## IMPACT SURVEY

In order to inform land managers of the impact of this epidemic on the timber resource and also to be better equipped to evaluate future outbreaks of this destructive beetle, it was felt that a good estimate of the volume of timber killed in 1966 was needed. Because of the large area involved, it did not appear that the cruising methods normally employed on more limited bark beetle infestations would fit this situation. Therefore, with the assistance of the Pacific Southwest Forest and Range Experiment Station, a combined aerial photo-ground survey was specially designed to measure the impact of the 1966 Douglas-fir beetle epidemic.

The results of the survey, completed August 2, 1967, are shown below:

| Area | Gross Volume of Douglas-Fir Killed in 1966 (In MMBF) | Net Volume of Douglas-Fir Killed in 1966 (In MMBF) | No. of Douglas-Fir Trees Killed in 1966 (THOUSANDS) |
|---|---|---|---|
| Entire 1.6 million acre infestation | 796 ± 14.7% * 1/ | 535 ± 13.9% * | 249 ± 13.7% * |
| Six Rivers N.F. | 376 | 253 | 119 |
| Klamath N.F. | 282 | 197 | 87 |
| Shasta-Trinity N.F. | 138 | 85 | 43 |

* At 1 standard deviation.

1/ By the end of the 1968 field season, the Forest Service hopes to recover 470 million board feet of this loss through salvaged timber sales.

### Sampling Design

A detailed account of the technical aspects of the survey will be published by the Pacific Southwest Forest and Range Experiment Station at a later date. Briefly, however, the sampling design used was stratified two-stage cluster sampling with random starts in the first stage and sampling proportional to size in the second stage.

The two forms of sampling in order of completion were:

1. Photo interpretation of 9 by 9-inch format, 1:8,000 color aerial transparencies. Interpretation involved the delineation of groups of Douglas-fir suspected to have been killed by beetles in 1966 and a count of the number of 1966 killed trees within each group.

2. Ground checks to determine the actual number of Douglas-fir killed by beetles in 1966 within selected groups delineated on the photos. In addition, the site class for each group visited was determined and the d.b.h. and Kimmey cull indicator for each 1966 killed Douglas-fir was recorded. From these data, individual gross and net tree volumes were calculated.

Stratification

In the fall 1966 aerial survey, the 1.6-million-acre infestation was stratified into two damage categories--areas of concentrated group-tree killing and areas of scattered group-tree killing. For this survey, however, the infestation was divided into five blocks of unequal size (see map). Blocks I and II were primarily scattered tree mortality; Blocks III and IV were a mixture of scattered and concentrated tree mortality, and Block V was primarily concentrated tree mortality. This breakdown resulted in three categories of tree mortality; namely, light (Blocks I and II), medium (Blocks III and IV) and heavy (Block V).

Photo Coverage

Photo coverage was of different intensity for each of the three categories of tree mortality.

Light category (Blocks I and II). Two flight lines were chosen at random within the first 12 miles from the western edge of each block; additional flight lines were spaced at 12-mile intervals from the first two. Stereo triplets[1/] were taken every 6 miles along the line of flight in Block I and 12 miles along the line of flight in Block II. The first triplet was taken at a randomly assigned distance within the block boundary depending upon the mile increments between photo samples (see table). The photo coverage was approximately 1.75 percent in the two "light" blocks (Blocks I and II).

---

1/ A stereo triplet consisted of three 9 by 9-inch color transparencies with 60 percent overlap taken at a scale of 1:8,000. The effective stereo coverage of the center photo was approximately 800 acres. At the time of interpretation a 1/2-inch strip around the edges of the center photo was omitted, therefore, approximately 640 acres were viewed on each triplet and comprised the photo sample.

Medium category (Blocks III and IV). Two flight lines were chosen at random within the first 9 miles, additional flight lines were spaced at 9-mile intervals. Stereo triplets were taken every 9 miles along the line of flight. The first triplet was taken at a random distance within the block boundary as above. The photo coverage was approximately 3.5 percent in the two "medium" blocks (Blocks III and IV).

Heavy category (Block V). Two flight lines were chosen at random within the first 6 miles; additional flight lines were spaced at 6-mile intervals. Stereo triplets were taken every 6 miles along the line of flight; the first triplet at a randomly chosen distance inside the block boundary (see table). Photo coverage was approximately 7 percent in the one "heavy" block (Block V).

Flight Operation

The photography was flown on June 8 and June 26-28. Two airplanes were used--the Aero Commander from the Pacific Southwest Forest and Range Experiment Station and the Cessna 180 from Region 6. Both planes were equipped with K-17 aerial cameras with 12-inch focal length lenses. Anscochrome D-200 color film was used on the entire job.

It was the responsibility of the pilot and the navigator to keep the plane on the assigned flight line, maintain proper altitude and to tell the photographer when to take the first frame of each triplet. This was all done with the aid of flight navigation charts, USGS 1:31,680 topographic maps on rollers, on which flight lines and triplet locations were premarked.

It was the responsibility of the photographer to maintain proper exposure settings, correct for drift, obtain proper photo overlap, and to keep track of the number of exposures by flight line and direction of flight.

Film processing and indexing was done by the Pacific Southwest Forest and Range Experiment Station.

Photo Interpretation

It took three men a total of 25 man days to complete the photo interpretation. Two entomologists and one forester from Region 5, Division of Timber Management, were assigned this task.

Old Delft scanning stereoscopes set on fluorescent light tables were used to view the transparencies. Grid overlays divided into one-inch squares facilitated systematic scanning.

The interpreters circled with red ink each group of dead trees suspected to have been killed by beetles in 1966 and numbered each group consecutively. Counts were made and recorded of the number of dead trees in each group.

The following is a more complete breakdown showing how the 106 total photo triplets were distributed throughout the infestation:

| Block No. | Category Of Tree Mortality | Flight Line Number Cluster A | Flight Line Number Cluster B | Flight Line Spacing (Miles) | Random Start In From Boundary To First Triplet | Distance Between Succeeding Triplets (Miles) | Number Triplets Taken Per Block |
|---|---|---|---|---|---|---|---|
| I | Light | 1 | 2 | 12 | Lines 1 & 2 - 2 miles | Line 1 - 6 miles<br>Line 2 - 12 miles | 7 |
| II | Light | 20, 22 | 21, 23 | 12 | Lines 20 & 22 - 4 miles<br>Lines 21 & 23 - 8 miles | 12 | 15 |
| III | Medium | 16, 19 | 17, 18 | 9 | Lines 16 & 18 - 8 miles<br>Lines 17 & 19 - 7 miles | 9 | 22 |
| IV | Medium | 12, 14 | 13, 15 | 9 | Lines 12, 14 & 15 - 3 miles<br>Line 13 - 6 miles | 9 | 11 |
| V | Heavy | 3, 5, 7, 9, 11 | 4, 6, 8, 10 | 6 | Lines 3, 5, 7, 9 & 11 - 4 miles<br>Lines 4, 6, 8, & 10 - 2 miles | 6 | 51 |
| TOTAL: | | 23 | | | | | 106 Triplets or 67,840 acres photographed and interpreted |

On completion of photo interpretation, groups of dead trees were selected for ground sampling by computer. The selections were based on probabilities proportional to tree count per group.

Ground Sampling

It took 98 man days for 19 men, working in crews of 2 to 3 men per crew, to ground check 53 plots during the 8-day period of July 26 through August 2, 1967. A cooperative task force of personnel from the Regional Office, the three National Forests involved, the California Division of Forestry, and the Pacific Southwest Forest and Range Experiment Station did this work.

To facilitate finding the plots on the ground, crews were supplied with 1:31,680 USGS topographic maps and 1/2"=1 mile district maps on which plot locations were shown, in addition to the photo triplets.

The data collected at each plot consisted of:

1. D.b.h. of all Douglas-fir killed by beetles in 1966.
2. Defect (Kimmey cull indicator) of all Douglas-fir killed by beetles in 1966.
3. Site--total height and age of 2-3 dominant trees on each plot.
4. The number of currently infested (1967 attacked) and the number of green uninfested Douglas-fir on the plot.
5. The number of currently infested and green uninfested Douglas-fir examined in a strip around the periphery of the sample plot.

All data was recorded in the standard cruiser's notebook, Timber Appraisal Cruise Record, form R5-2400-28A, revised December 1964. A separate notebook was used for each plot.

Cost

Total cost of the survey excluding design, determination of plot volumes and analysis came to $9,607.00 or $0.006 per acre for the entire 1.6 million-acre infestation. An itemized breakdown of the costs by

sampling follows:

| Photo Plots | | Ground Plots | |
|---|---|---|---|
| Aircraft - - - - - - - - - - | $1,024.00 | Preparation of field maps (6 man days @ 8 hours/day @ $4.25/hour - - - - - - - - - | $ 204.00 |
| Film, processing and editing - - - - - - | 500.00 | Cruising (98 man days @ 8 hours/day @ $4.25/hr.) - - | 3,332.00 |
| Per diem for photo crew - - - - - - - | 150.00 | Helicopter for transportation of field crews, plus cost of helicopter service truck | 1,650.00 |
| Photo crew's salaries (15 man days @ 8 hrs./day @ $5.00/hour) - - - - - - | 600.00 | Per diem for field crews | 1,252.00 |
| Interpretation (25 man days @ 8 hrs./day @ $4.13/hour) - - - - - - - | 825.00 | | |
| Miscellaneous - - - - - - | 50.00 | Miscellaneous | 20.00 |
| Total Cost | $3,149.00 | Total Cost | $6,458.00 |
| Number of plots | 1,380 | Number of plots | 53 |
| Cost per plot | $ 2.28 | Cost per plot | $ 121.85 |

Determination of Plot Volumes

The following procedure was used to determine the gross and net volume of Douglas-fir killed in 1966 on each ground plot.

1. Site index for each plot was determined by referring to the Site Curves on page 3, Section 3.22 of R-5 Supplement No. 89, Timber Sale Preparation and Appraisal Handbook, dated October 1, 1966.

2. Individual gross tree volume was determined from the Tenth-Inch Volume Tables for the Commercial Conifer Species of California compiled by Forest Survey, California Forest and Range Experiment Station, January 1956, pages 13-18.

3. Using the coded cull indicators, the merchantability factor for each tree was determined by referring to the Douglas-fir Merchantability Factors in Appendix E, Section 3.4 of R-5 Supplement No. 89, Timber Sale Preparation and Appraisal Handbook, dated October 1, 1966.

4. Individual net tree volume was calculated by multiplying gross tree volume by its corresponding merchantability factor.

Analysis

A computer program written by the Pacific Southwest Forest and Range Experiment Station analyzed the plot data, the results of which have been reported previously (see page 4). Also, a very high correlation coefficient ($\gamma$=0.97) was shown to exist between photo estimates of numbers of dead trees versus ground "truths."

## DISCUSSION

Normally, because of storms and timber sale related activities, a small, scattered amount of slash, suitable for Douglas-fir beetle breeding, is produced each year in the north coast of California. Usually, this scattered slash is only enough to perpetuate the Douglas-fir beetle in an endemic nature. It appears then that the principal factor which provoked the tremendous buildup of beetles in 1965 and subsequent catastrophic tree mortality in 1966 was the widespread, large, concentrated accumulations of downed host material; the result of violent storms and severe flooding of December 1964. The abundance of favorable host material enabled the endemic 1964 beetle population to increase to an overwintering epidemic population in 1965. In the spring of 1966, the emerging epidemic population, after first saturating the small, scattered accumulations of suitable slash which developed prior to emergence, then had no alternative but to attack standing green trees.

Aided by the warm, dry conditions that prevailed during April through June 1966 flight period, the "en masse" attacks were sufficient to kill the trees. This is true, yet there are indications that the natural resistance of the green trees to attack, plus poor brood survival in green trees, brought about the sharp reduction in the beetle population by winter of 1966.

While tree killing is continuing in 1967, the magnitude of the problem is drastically lower than in 1966. Again, this can be attributed to (1) a lower overwintering population in 1966 than in 1965, (2) wetter, cooler conditions during the 1967 flight period than in 1966, and (3) the natural resistance of green trees to successful attack.

The aerial photo-ground survey technique used to measure the impact of the 1966 Douglas-fir beetle epidemic proved to be very effective as attested by the very low errors of the estimates that were obtained. The very high correlation coefficients between the photo interpreter estimates versus ground "truths" reflect the worth of the large-scale color aerial transparencies.

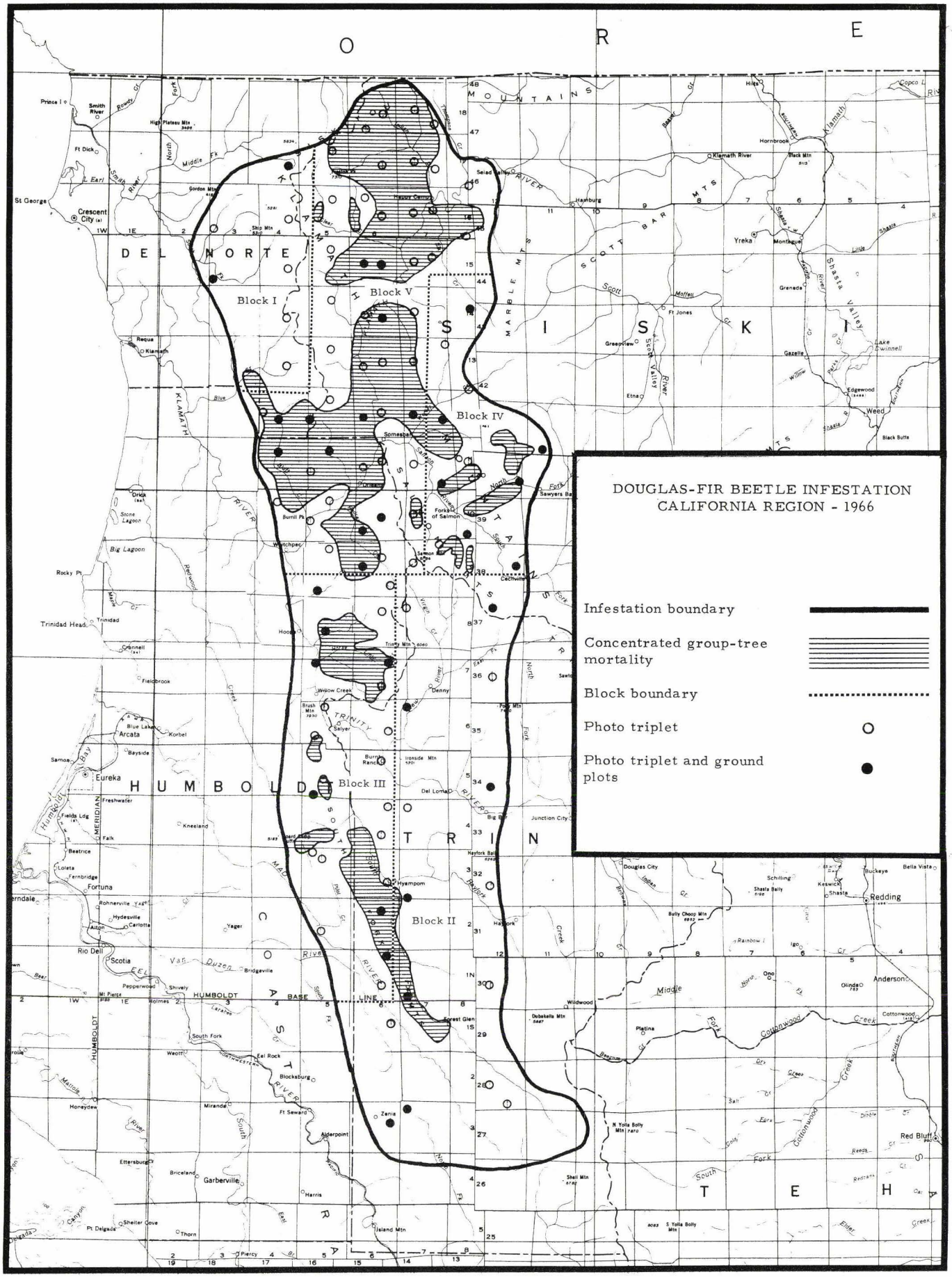
## RECOMMENDATIONS

1. In light of what happened following the December 1964 storms and floods, it is apparent that if in the future a similar event should occur, all efforts should be made to salvage or remove the slash before the beetles can emerge to attack standing green trees. If in turn green trees are attacked, they should be salvaged before the next brood can emerge.

2. Because of the vast resource of Douglas-fir on the West Coast and its importance to the economy and because of the serious impact the Douglas-fir beetle can have on this resource, a program of basic research needs to be undertaken to (1) determine why Douglas-fir beetle populations rise and decline, (2) determine the means of predicting when populations will increase and decrease, and (3) discover ways to supplement salvage logging to prevent and control tree killing by this beetle.

3. On future large-scale epidemics of this insect or any other forest insect, consider using an aerial photo-ground survey the same as or similar to the one reported here to measure the impact of the epidemic on the forest resource. Also, the wealth of information that can be obtained from 9 by 9-inch color aerial transparencies with scales of about 1:8,000 suggests that their use should be considered as a part of the regular forest insect evaluation procedure.

Attachment (map)


DOUGLAS-FIR BEETLE INFESTATION
CALIFORNIA REGION - 1966
Infestation boundary
Concentrated group-tree mortality
Block boundary
Photo triplet
Photo triplet and ground plots
Block I
Block II
Block III
Block IV
Block V
DEL NORTE
HUMBOLDT
TRINITY
SISKIYOU
SHASTA
TEHAMA
MOUNTAINS
SCOTT BAR MTS
MARBLE MTS
Redwood Creek
Smith River
Klamath River
Trinity River
Eel River
Mad River
Van Duzen River
Scott River
Shasta Valley
Sacramento River
Cottonwood Creek
Eureka
Arcata
Crescent City
Yreka
Weaverville
Redding
Red Bluff
Hoopa
Somes Bar
Orleans
Happy Camp
Seiad Valley
Hamburg
Hornbrook
Montague
Grenada
Gazelle
Weed
Etna
Fort Jones
Greenview
Scott Valley
Lake Shasta
Lake Siskiyou
Lake Shastina
Lake Gwinnell
Edgewood
Black Butte
Requa
Klamath
Orick
Big Lagoon
Trinidad
Rocky Pt
Cannell
Fieldbrook
Blue Lake
Korbel
Bayside
Samoa
Freshwater
Fields Ldg
Falk
Kneeland
Beatrice
Loleta
Fernbridge
Fortuna
Rohnerville
Hydesville
Carlotta
Alton
Yager
Rio Dell
Scotia
Pepperwood
Shively
Bridgeville
Weott
South Fork
Eel Rock
Blocksburg
Miranda
Ft Seward
Alderpoint
Zenia
Honeydew
Ettersburg
Briceland
Garberville
Harris
Island Mtn
Shelter Cove
Ft Delgada
Thorn
Piercy
Hyampom
Hayfork
Junction City
Del Loma
Burnt Ranch
Salyer
Willow Creek
Denny
Hoopa
Trinity Mtn
Burnt Pk
Somes Bar
Forks of Salmon
Sawyers Bar
Cecilville
Callahan
Douglas City
Schilling
Shasta Bally
Keswick
Shasta
Buckeye
Bella Vista
Bally Cheap Mtn
Rainbow
Igo
Oak Run
Olinda
Anderson
Cottonwood
Platina
Dubakella Mtn
Wildwood
Forest Glen
N Yolla Bolly Mtn
S Yolla Bolly Mtn
Shell Mtn
Dobbins
Oroville
Paradise
Chico
Red Bluff
Corning
Tehama
Los Molinos
Vina
Gerber
Proberta
Dairyville
Paskenta
Elder Creek
Thomes Creek
Stony Creek
Grindstone Creek
Cold Fork
Middle Fork
North Fork
South Fork
Humboldt Meridian
Humboldt Base Line
Mt Pierce
Mt Diablo Base Line
Mt Diablo Meridian